CHAPTER 3

SOME EXTENSIONS AND REFINEMENTS OF THE THEORY: A LIFE-CYCLE MODEL OF RISK CHOICE

In the previous chapter it was shown that hedonic wage-risk studies, by assuming individuals correctly calculate their job-related risks of death, yield MVS estimates which are biased and inconsistent. Further, it was noted that in order to measure a person's perceptions of risk, and hence estimate subjective evaluations of risk reduction, the refinement of survey techniques is worthy of greater attention. In this chapter another potential bias, which may be inherent in hedonic wage-risk methods, is explored and is offered as another justification for using the contingent valuation approach in estimating evaluations of safety.

The bias in hedonic wage-risk studies described here stems from a potential violation of the assumption that the labor market operates freely and is in equilibrium. When this assumption is violated, the labor market is said to experience structural constraints. Such constraints on the labor market can be shown diagramatically to render a situation in which the hedonic wage gradient is not tangent to workers' indifference curves as was the case in Figure 2.4. Rather, at an observed market level of risk and wages, the worker's maximum level of expected utility intersects the hedonic wage gradient.

That the hedonic wage gradient may be comprised of a locus of indifference curve intersections rather than tangencies, suggests that a "wedge" is formed between how the market transforms risk into wealth (as described by the slope of the hedonic wage gradient) and a worker's marginal value of safety (as described by the slope of the indifference curve).

This leads to two possibilities. Figure 3.1.1 shows the first case. In this situation Θ^1 and Θ^2 are two different levels of expected utility for the same worker where Θ^2 is greater than Θ^1. Further, the hedonic wage gradient is described by $WLTH(\pi)$. If the labor market is operating freely, this worker will maximize expected utility by choosing a level of job related risk equal to π_2. In this situation, the worker's MVS (as described by the slope of Θ^2) is equal to the rate at which the market compensates workers for taking risk (as described by the slope of $WLTH(\pi)$). Therefore, if one was to estimate $WLTH(\pi)$, calculate $WLTH'(\pi\ )$, and interpret the former as the worker's subjective MVS, one would be correct in doing so.

However, if the worker was constrained to stay in a job with risk level π_1, maximum level of expected utility is Θ^1. At a level of risk equal to π_1, the rate at which the market compensates risk-bearing, $WLTH'(\pi_1)$, is less than the worker's subjective MVS_1 (i.e., slope of Θ_1). A "wedge" is described by $MVS_1 - WLTH'(\pi_1)$ and, therefore, $WLTH'(\pi_2)$

underestimates the worker's subjective evaluations. The opposite situation is described in Figure 3.1.2.

In this chapter, two sources of the aforementioned "wedge" will be discussed. The first is attributed to the worker-consumer's increasing risk-aversion through time, and the increased transaction costs he faces in changing jobs: referred to as "risk rigidities." The second stems from asymmetry in the capital market.

The theory developed in this chapter is based on an intertemporal model of career choices under uncertainty. This model can be used to elicit a marginal value of safety directly from analyzing the decision process an individual goes through in choosing a job. Differences in potential jobs are quantified in terms of perceived job related risks of death. Therefore, by picking a level of perceived risk the individual has chosen a career.

In the model, the individual maximizes expected life time utility subject to an intertemporal budget constraint. The model consists of three periods: the training period, the working period, and the retirement period. The more risky a job the individual chooses the less likely that individual is to realize future utility. However, it is assumed that job-related risk and wealth are positively related, ceteris paribus. The results of this model reveal reasons to believe there exists a wedge between how the market would transform job-related risk into wealth and an individual's MVS.

3.1 THE SIMPLE MODEL

3.1.1. A Life-Cycle Mode of Risk Acceptance

The theory of an individuals' career choice developed here is framed within a three period life-cycle model with a risk of death in each period. It is assumed that the individual's most income-productive years are towards the middle of the life-cycle with income earned during these years used to finance consumption during retirement and perhaps to pay off debts cumulated in the early years. Thus, the model here has an Ando-Modigliani (1963) flavor with the career decision viewed as one which affects all periods in an individual's life. Further, each period has a "life" state and a "death" state with the career choice affecting the probability of each state within the last two periods. Therefore, the decision of which career to enter will affect the individual's life cycle via the income the career renders and the risk associated with that particular job. Moreover, an MVS term is derived directly from the calculus.

Although there has been some attempt in the safety literature to derive an MVS from a life-cycle model (e.g., Blomquist, 1979), this model is novel in that the individual is assumed to re-evaluate his career choice (i.e., choice of job-related risk) at various points within the life cycle. This formulation affords the opportunity to examine how attitudes towards risk change during the course of one's life. Since an individual's

Figure 3.1.1: Market Transformation of Risk to Wealth (1)

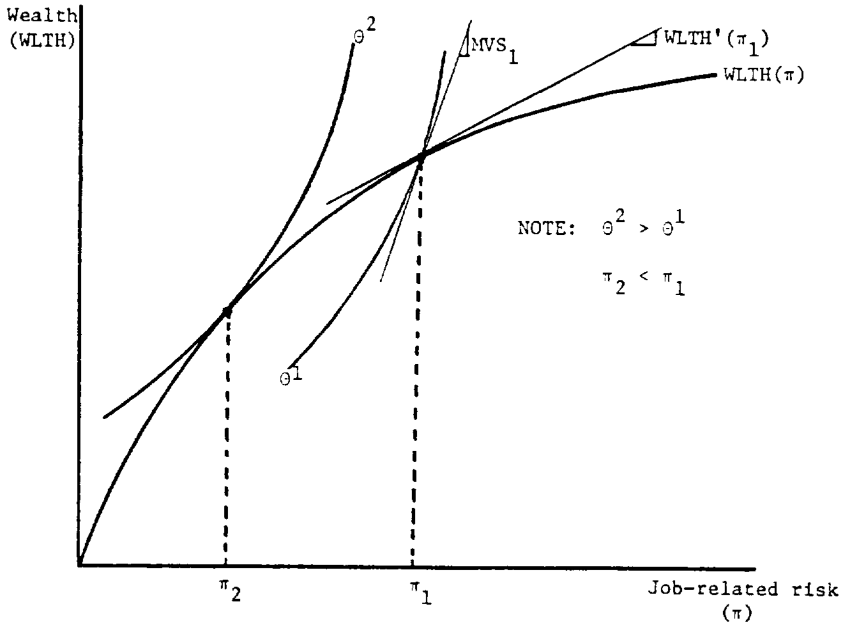
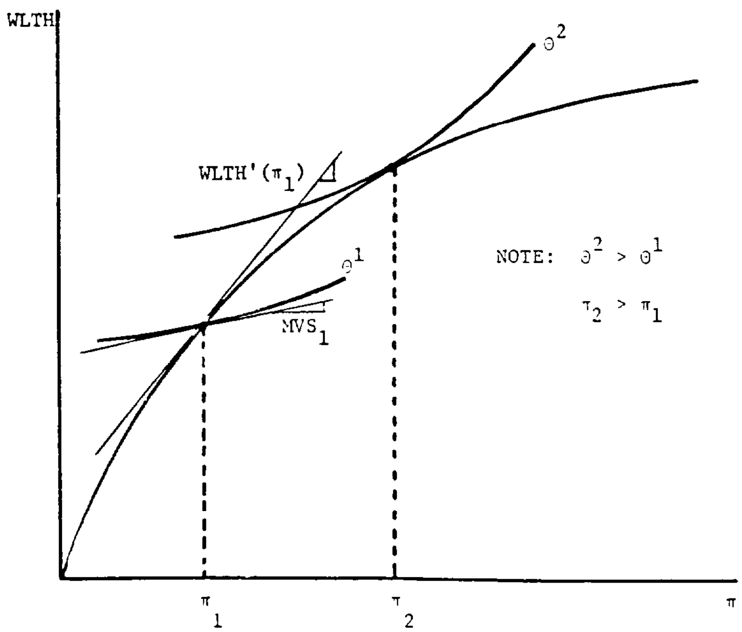


Figure 3.1.2: Market Transformation of Risk to Wealth (2)



preference towards risk is an important factor in his subjective MVS, it is felt that the examination of how these preferences change is a worthy endeavor.

To simplify the analysis, an individual's life is partitioned into four periods with each period's utility assumed to be a function of consumption in that period. The first period, period zero, is childhood. Here the child's consumption level is given to him by his parents. Therefore, consumption, and hence utility, in this period is assumed to be exogenous to the model. It should be noted, however, that an individual's optimal choice of job-related risk will be affected by his initial endowment of wealth given to him by his parents. Viscusi (1978b) sets up a one period expected utility model and concludes that the more assets, or exogenous consumption, an individual inherits from his parents, the less job-related risk he will accept. However, since we are examining decisions that the person has control over, this period is not included in the model. It is also assumed that the individual does in fact live through childhood.

After childhood, the individual is faced with the decision of what career to enter. It is therefore at the beginning of this period, period one, that the person makes a career choice. The rational individual is aware of the fact that this decision will affect his lifetime stream of utility.

Period one is assumed to be a period of training for the individual's career. Examples of such training could be enrollment in college, vocational schools, or apprenticeship programs. Earnings in this period are so small compared to income made on the job that they are assumed to be zero. Therefore, consumption in period one is financed through borrowing on future income. Elimination of this period due to the fact that some people do not go through training periods does not affect the basic results of the model.

Period two is then defined as the time in which the individual is actually working in his career. It is assumed that this is the only period in which the person earns income. Therefore, this income must be optimally distributed among the three periods since the person must (1) pay back loans taken out for period one's consumption, (2) consume some positive quantity in the second period, and (3) save for consumption in period three. It follows that period three is the retirement years.

In order to quantify the vector of possible careers, each potential job is described in terms of its perceived job-related risk of death. Clearly, each job is described by other characteristics other than risk but the relevant job attribute here is risk. Therefore, for the purposes of this model, by choosing a career, the individual chooses a level of job-related risk of death.

If the individual chooses a relatively risky job, the probability of living through periods two and three decreases, as do the odds of realizing utility in these periods. However, the benefit in taking such risk stems from the fact that riskier jobs yield higher incomes, ceteris paribus. As Viscusi (1978a) points out, the positive nature of this relationship is not an assumption but rather is a result of the nature of the job choice problem. He adds that, "the derivation of this result [does] not require that workers be risk averters. The only assumption required [is] that [a] good health state be more desirable than [an] ill health state."

That people engage in various consumption activities, other than work, which yield positive utility and increase the odds of dying (e.g., smoking), will not be of concern to this model. Such risks will be referred to as exogenous risk of death. This is done because the model concerns career decisions. Therefore, it is assumed that the only thing an individual does to affect his probability of death is the career choice. Further, since the individual only works in the second period, this is the only period where risk of death has an endogenous element. Given this, the probability of death is defined as follows:

π_1 = exogenous risk of death in period 1

π_2 = risk of death in period 2

$= \pi_2^\circ + \hat{\pi}_2$

where:

π_2° = exogenous risk of death in period 2

π_2 = level of additional risk due to job-related hazards

π_3 = exogenous risk of death in period 3.

It follows that;

$(1-\pi_1)$ = probability of living through period 1

$(1-\pi_2)$ = probability of living through period 2; given that the individual survived through period 1

$(1-\pi_3)$ = probability of living through period 3; given that the individual survived through periods 1 and 2.

Typically $\pi_2^\circ < \pi_1, \pi_3$.

Since $(1-\pi_i)$ is the probability of living through period i given that the individual has survived through all previous periods, $(1-\pi_i)$ is actually a conditional probability. Assuming that π_i is independent of π_j, the following expressions represent the unconditional probabilities of survival:

$(1-\pi_1)$ = probability of surviving to the end of period 1

$(1-\pi_1)(1-\pi_2)$ = probability of surviving to the end of period 2

$(1-\pi_1)(1-\pi_2)(1-\pi_3)$ = probability of surviving to the end of period 3.

Because exogenous risk of death is typically lowest in period two, an individual may not be too hesitant to increase π_2 (by increasing $\hat{\pi}_2$). This may be especially true in light of the fact that income in period two increases as the individual takes on more risk and that income must be distributed among the three periods. The positive relationship between risk and wages is given by the hedonic wage-risk gradient the individual faces in period two:

$$y_2 = y_2(\hat{\pi}_2)$$

where $\frac{dy_2}{d\hat{\pi}_2} > 0$ and where y_2 is defined as the income in period two.

An additive expected life time utility function is assumed which takes the form:

$$E(U^L) = E(U_1) + E(U_2) + E(U_3)$$

where $E(U_1) = (1-\pi_1)U_1(c_1) \equiv$ expected utility in period 1

$E(U_2) = (1-\pi_1)(1-\pi_2)U_2(c_2) \equiv$ expected utility in period 2

$E(U_3) = (1-\pi_1)(1-\pi_2)(1-\pi_3)U_3(c_3) \equiv$ expected utility in period 3

$U_i(c_i) \equiv$ utility in period i as a function of that period's consumption level.

Finally, the individual faces the following typical intertemporal budget constraint:

$$y_1 + \delta y_2 + \delta^2 y_3 = c_1 + \delta c_2 + \delta^2 c_3$$

where:

$y_i \equiv$ income in period i

$c_i \equiv$ consumption in period i

$\delta \equiv 1/(1+r)$

$r \equiv$ the real rate of interest.

Since it is assumed that $y_1 = y_3 = 0$, $y_2 = y_2(\hat{\pi}_2)$ and because wealth, WLTH, is defined as the present discounted value of future earnings, the constraint reduces to:

$$\text{WLTH} \equiv \delta y_2(\hat{\pi}_2) = c_1 + \delta c_2 + \delta^2 c_3 \tag{1}$$

It should be noted that although utility in each period is uncertain due to the probability of death, it is assumed, for simplicity, that there is certainty over income. Therefore, there are no added complications involved in transferring income from one period to another, or more precisely, distributing consumption among periods. Also, r is assumed to be known and constant throughout all periods.

We can now set up the individual's maximization decision which is made at the beginning of period one. It is as follows:

$$\max \quad E(U^L) \text{ with respect to } c_1, c_2, c_3, \hat{\pi}_2$$

$$\text{subject to} \quad WLTH(\hat{\pi}_2) = c_1 + \delta c_2 + \delta^2 c_3$$

At this point the assumptions on the expected lifetime utility function, $E(U^L)$, should be explained. The type of structure to impose on the utility function is controversial. One must weigh the benefits of greater generality with the costs of possible intractability. There are basically three types of general structures that have been imposed on intertemporal models of utility. First, one can express lifetime utility, U^L, in the following most general manner:

$$U^L = U^L(c_1, c_2, \ldots, c_n) \qquad \frac{\partial^2 U^L}{\partial c_i \partial c_j} \neq 0 \,. \tag{2}$$

The second structure often imposed is to assume a separable U^L but allow the utility functions from one period to another to be different. This structure allows for the fact that individual characteristics, or tastes, may change from one period to another. Within this structure we express U^L as

$$U^L = U_1(c_1) + U_2(c_2) + U_3(c_3) \,. \tag{3}$$

The third assumption often used is that the utility function is the same in each period and only the arguments change. That is:

$$U^L = U(c_1) + U(c_2) + U(c_3) \,. \tag{4}$$

Often when structure (4) is used, the individual is also assumed to be myopic. In other words, the individual is assumed to have a rate of time preference with respect to utility. This suggests that people discount future utility since they may prefer present utility to future utility. This modifies (4) in the following manner:

$$U^L = U(c_1) + \left(\frac{1}{1+\rho}\right)U(c_2) + \left(\frac{1}{1+\rho}\right)^2 U(c_3) \tag{4'}$$

where ρ = rate of time preference.

Immediately one can see the advantages of using (3) over (4'). That is, the utility functions in (3) can differ from period to period either because the functional form changes from period to period or they can change merely because people are myopic. In other words, since (3) is more general than (4') the former could employ the same assumptions as the latter by assuming that:

$$U_1 = U(c_1)$$

$$U_2 = \left(\frac{1}{1-\rho}\right)U(c_2)$$

$$U_3 = \left(\frac{1}{1+\rho}\right)^2 U(c_3)$$

The model in this section assumes that U^L takes the form of (3); that is, U^L is separable with different utility functions across periods. In this manner utility in each period is assumed to be independent of the arguments in the other periods' utility functions. This loss of generality makes the problem tractable, makes the first order conditions relatively easy to interpret, and, for this model, is a realistic assumption. In this model separability is a realistic assumption for two reasons: (1) the three periods are distinctly different in nature, and (2) each period covers a relatively long period of time. With respect to the second, if each period were one day (or even one year) it might be questionable to assume, for example, that the utility of eating a steak today is independent of whether or not a steak was eaten yesterday. However, it is not as controversial to say that the utility of eating a steak today is independent of whether or not a steak was eaten five years ago.

Also, this model assumes no bequest value. In other words, it would be more precise to say that expected utility in a given period, E(U), is actually:

$$E(U) = (1-\pi)U + \pi\bar{u}$$

where π = risk of death

U = utility in life

$\bar{U}$ = utility in death.

Assuming that $\bar{U}$ is very small relative to U, $\bar{U}$ can be said to be approximately equal to zero. Thus, E(U) reduces to:

$$E(U) = (1-\pi)U.$$

Further, the following typical assumptions on each period's utility function are also made:

$$\frac{\partial E(U_i)}{\partial c_i} > 0 \qquad \frac{\partial^2 E(U_i)}{\partial c_i^2} <$$

Finally, one need not feel uneasy about the fact that there is the possibility that the individual may borrow money on future earnings and then die before he or she pays back the loan. This is a risk incurred on the bank not the individual and is incorporated in the interest rate.

With this information in hand we can formally state the individual's maximization problem as follows:

$$\max$$

$$E(U^L) = (1-\pi_1)U_1(c_1) + (1-\pi_1)(1-\pi_2)U_2(c_2) + (1-\pi_1)(1-\pi_2)(1-\pi_3)U_3(c_3)$$

subject to: $WLTH(\hat{\pi}_2) = c_1 + \delta c_2 + \delta\ c_3^2$

The lagrangian is therefore:

$$L = E(U^L) + \lambda[WLTH(\hat{\pi}_2) - c_1 - \delta c_2 - \delta^2 c_3].$$

The first order conditions from this maximization problem are as follows:

$$\frac{\partial L}{\partial c_1} = (1-\pi_1)U'_1 - \lambda = 0 \tag{5}$$

$$\frac{\partial L}{\partial c_2} = (1-\pi_1)(1-\pi_2)U'_2 - \delta\lambda = 0 \tag{6}$$

$$\frac{\partial L}{\partial c_3} = (1-\pi_1)(1-\pi_2)(1-\pi_3)U'_3 - \delta^2\lambda = 0 \tag{7}$$

$$\frac{\partial L}{\partial \hat{\pi}_2} = -(1-\pi_1)U_2 - (1-\pi_1)(1-\pi_3)U_3 + \lambda \frac{dWLTH}{d\hat{\pi}_2} = 0 \tag{8}$$

where $U'_i \equiv \frac{dU_i}{dc_i}$

conditions (5)-(7) imply respectively:

$$\lambda = (1-\pi_1)U'_1 \tag{5'}$$

$$\frac{\lambda}{(1+r)} = (1-\pi_1)(1-\pi_2)U'_2 \tag{6'}$$

$$\frac{\lambda}{(1+r)^2} = (1-\pi_1)(1-\pi_2)(1-\pi_3)U'_3 \tag{7'}$$

These are standard utility conditions put into an intertemporal expected utility framework. By the envelope theorem, λ is the marginal utility of wealth. Therefore, conditions (5')-(7') imply that, at the optimum, the discounted marginal utility of wealth equals the expected marginal utility of consumption. This is nothing more than a marginal cost equals marginal benefit condition. The right-hand-side in (5')-(7') is the expected marginal utility (benefit) of consumption; that is, an increase in wealth leads to an increase in consumption and hence utility. The left-hand-side in (5')-(7') is the discounted shadow price of wealth. This price must be discounted and is, therefore, highest in the first period (as shown by (5')) since the opportunity cost of consumption in the first period is the highest. This is because a unit of consumption in the first period could have been in the bank for the longest period of time and thus could have rendered a higher level of consumption in the future.

Solving for λ in the first order conditions implies yet another standard utility maximization condition. If we then equate (5) and (6), (6) and (7), and then (5) and (7) respectively, we get the following conditions:

$$\frac{E[U'_1]}{E[U'_2]} = (1+r) \tag{9}$$

$$\frac{E[U'_2]}{E[U'_3]} = (1+r) \tag{10}$$

$$\frac{E[U'_1]}{E[U'_3]} = (1+r)^2 \tag{11}$$

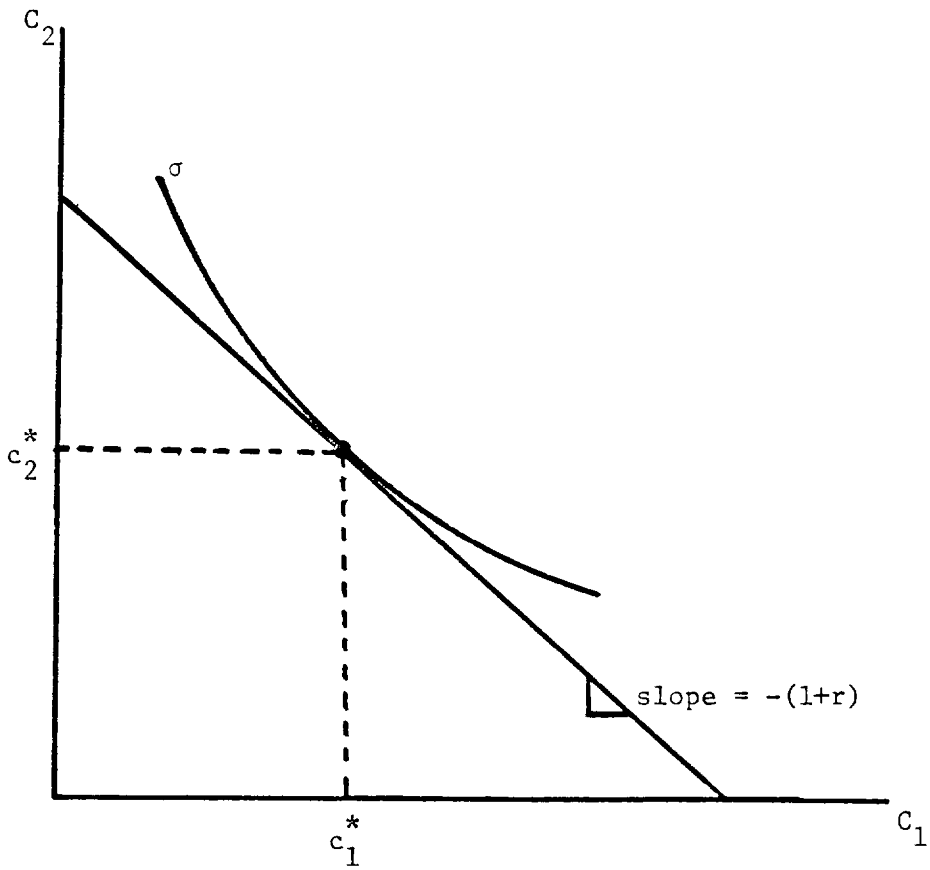
where $E[U'_j] = \prod_{i=1}^{j} (1-\pi_i)U_j$

and E is the expectations operator.

The left-hand side of (9)-(11) is the marginal rate of substitution of c_i for c_i ($i \neq j$; i, j = 1, 2, 3) expressed in expected value terms. This denotes the subjective manner in which the individual would like to substitute a unit of c_i for a unit of c_j. The right-hand side of (9)-(11), on the other hand, represents the marginal rate of transformation of c_i for c_j, MRT_{ij}. MRT_{ij} expresses the objective manner in which the individual can transform a unit of c_i for a unit of c_j. Given convex indifference curves, when these conditions are met, interior solutions for maximum expected utility are obtained.

Figure 3.2 graphically represents condition (9). In this figure the expression (l+r) implies that the individual can transform one unit of c_2 into one unit of c_1 at (l+r). In other words, every unit of cl must be paid back, with interest, during period two. This implies that in total c_1(l+r) must be paid back leaving this same amount unavailable for consumption in period two. Similarly, the individual can postpone a unit of c_2, put it in the bank, and render (l+r) available for consumption in period three. In Figure 3.2, given a convex indifference curve, σ, the optimal values are described by c_1^* and c_2^*.

Figure 3.2: Intertemporal Equilibrium



That these standard intertemporal utility maximization conditions (in expected value terms) fall from the model suggests that the model is correctly set up. Although these conditions are not in themselves earthshattering, they lend credibility to other conditions which follow from the maximization procedure. In particular, we are interested in the type of job (defined above as the level of job-related risk of death) the individual chooses. Recall from the maximization problem that:

$$\frac{\partial L}{\partial \hat{\pi}_2} = -(1-\pi_1)U_2 - (1-\pi_1)U_3 + \lambda \frac{dWLTH}{d\hat{\pi}_2} = 0$$

which implies: $\lambda \frac{dWLTH}{d\hat{\pi}_2} = (1-\pi_1)U_2 + (1-\pi_1)(1-\pi_3)U_3$

$$\frac{dWLTH}{d\hat{\pi}_2} = \frac{(1-\pi_1)U_2 + (1-\pi_1)(1-\pi_3)U_3}{\lambda}$$

$$WLTH'(\hat{\pi}_2) = \frac{(1-\pi_1)(1-\pi_2)U_2 + (1-\pi_1)(1-\pi_2)(1-\pi_3)U_3}{\lambda(1-\pi_2)} \qquad (8')$$

The left-hand side of (8') is the marginal benefit of taking on more risk: the amount present discounted earnings (earnings in period two) increase with an increase in π_2. Remember that since the individual is making the career decision at the beginning of period one, income from period two will be discounted. The left-hand side of (8') is merely the slope of the hedonic wage-risk gradient. In order to interpret the right-hand-side of (8') we must return to the objective function, $E(U^L)$. Totally differentiating $E(U^L)$ and combining like terms yields:

$$E(U'_1)dc_1 + E(U'_2)U'_2dc_2 + E(U'_3)U'_3dc_3$$
$$- [(1-\pi_1)U_2 + (1-\pi_1)(1-\pi_3)U_3]d\hat{\pi}_2 = dE(U^L) \qquad (12)$$

Suppose we ask the question how much must we change the present discounted value of income from period two, given a change in π_2, in order to keep $E(U^L)$ at the same level (i.e. $dE(U^L) = 0$). This is nothing more than a compensating variation measure given a change in π_2. In deriving this compensating variation it is assumed that the individual distributes the additional wealth needed to maintain a given $E(U^L)$ optimally between the three periods. Returning to our first order conditions and solving for U'_i in (5), (6) and (7) we find that an optimal allocation of a change in wealth requires that:

$$U'_1 = \frac{\lambda}{(1-\pi_1)} \qquad (5'')$$

$$U'_2 = \frac{\lambda}{(1-\pi_1)(1-\pi_2)(1+r)} \qquad (6'')$$

$$U'_3 = \frac{\lambda}{(1-\pi_1)(1-\pi_2)(1-\pi_3)(1+r)^2} \tag{7"}$$

substituting (5"), (6"), and (7") into (12), setting $dE(U^L) = 0$, and combining like terms implies that:

$$\lambda[dc_1+\delta dc_2+\delta^2 dc_3] = [(1-\pi_1)U_2+(1-\pi_1)(1-\pi_3)U_3]d\hat{\pi}_2 \tag{13}$$

Recall the intertemporal budget constraint from equation (1):

$$\delta y_2(\hat{\pi}_2) = c_1 + \delta c_2 + \delta^2 c_3$$

or $$WLTH = c_1 + \delta c_2 + \delta^2 c_3$$

totally differentiating (1) yields:

$$dWLTH = dc_1 + \delta dc_2 + \delta^2 dc_3 \tag{14}$$

substituting (14) into (13) yields:

$$\lambda dWLTH = [(1-\pi_1)U_2 + (1-\pi_1)(1-\pi_3)U_3]d\hat{\pi}_2$$

$$\frac{dWLTH}{d\hat{\pi}_2} = \frac{[(1-\pi_1)U_2 + (1-\pi_1)(1-\pi_3)U_3]}{\lambda}$$

$$\frac{dWLTH}{d\hat{\pi}_2} = \frac{[(1-\pi_1)(1-\pi_2)U_2 + (1-\pi_1)(1-\pi_2)(1-\pi_3)U_3]}{\lambda(1-\pi_2)} = MVS_1 \tag{15}$$

$$MVS_1 = \frac{E(U_2) + E(U_3)}{\lambda(1-\pi_2)} \tag{15'}$$

This compensating variation, therefore, measures the individual's marginal value of safety, MVS_1. MVS_1 is the amount of wealth an individual will subjectively require in order to take on an additional amount of risk in period two as seen from a period one perspective. As was shown in chapter 2, Mvs > 0. A relatively low value of MVS_1 implies that the individual exhibits a relatively low risk-averse preference and therefore does not require much compensation for taking on π_2.

Therefore, from conditions (8') and (15) we can conclude that:

$$WLTH'(\hat{\pi}_2) = MVS_1 \tag{16}$$

From equation (15') we can see that the magnitude of MVS_1 depends on the levels of $E(U_2)$ and $E(U_3)$ (which in turn depend on U_2, U_3 and on π_1, π_2, and π_3) and λ: the marginal utility of wealth.

This suggests that if an individual expects high levels of utility in the future (i.e., periods two and three) this person will have a relatively high MVS and may be adverse towards entering high risk careers. Also, a low marginal utility of wealth means that for a given level of $WLTH'(\pi_2)$, the amount by which this increases $E(U^1)$ is relatively low. It is, therefore not surprising that this person will be more adverse towards taking a risky career since the benefits are relatively low. This is reflected in a high MVS_1.

Figure 3.3 shows the hedonic wage gradient, $WLTH(\pi_2)$, the individual faces in the above maximization problem. Further, the indifference curves for two different individuals are given as Θ^{**} (for a risk-averse individual) and Θ^* (for a risk-loving individual). The risk averse worker consumer satisfies condition (16) by choosing to train for a low risk career, π_2^{**} while the risk-loving worker-consumer chooses to train for the higher risk career π_2^*.

The results obtained to this point suggest that MVS estimates from hedonic wage-risk studies, if modified to measure perceived risk, accurately reflect subjective evaluations of risk reductions (as shown by the similarity between Figure 3.3 and Figure 2.4). However, since this is a life cycle model, the question naturally arises will the choice of an optimal job-related risk made at the beginning of period one remain optimal throughout the individual's life?

If the individual at some future point in time re-evaluates the above maximization problem and the optimal level of job-related risk does not change, this individual is said to exhibit dynamic consistency. If, after re-evaluating, the optimal level of risk changes, dynamic inconsistency is said to be observed.

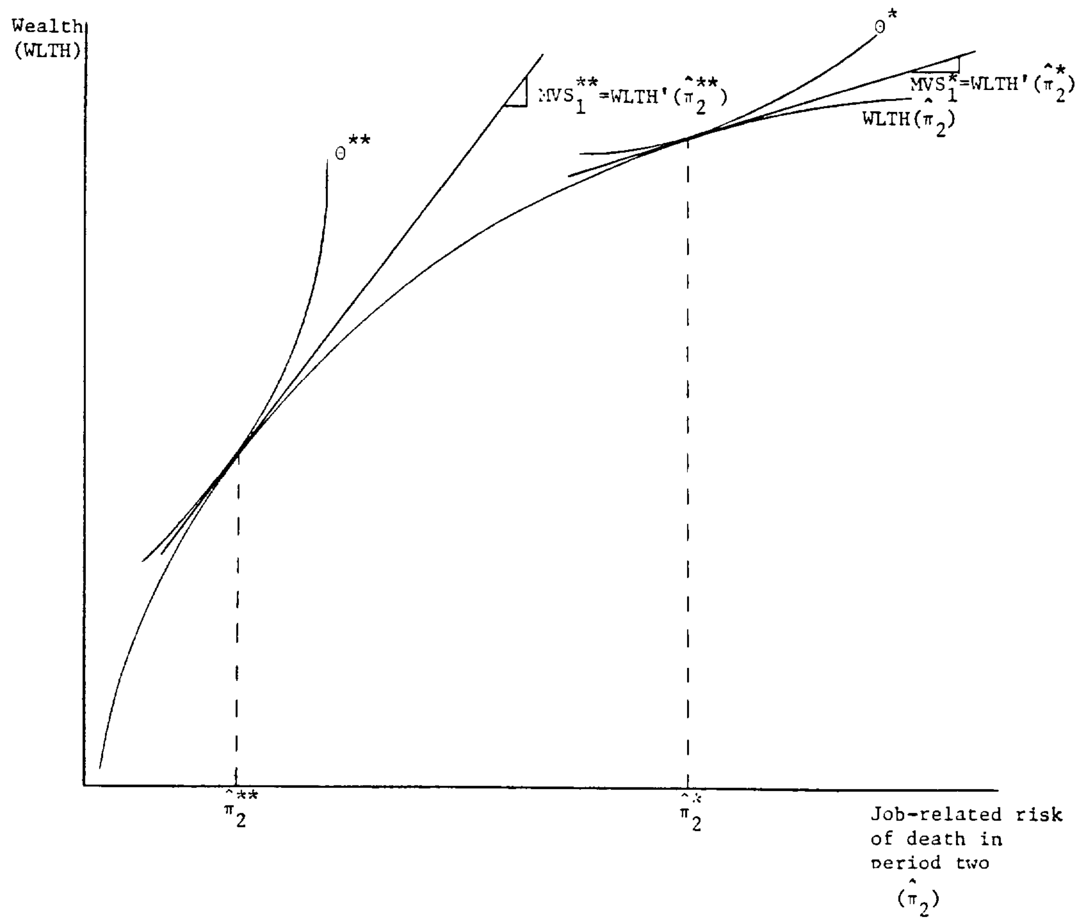
It will be shown in the next section that dynamic consistency will only result under extremely heroic assumptions. Therefore, the worker-consumer is eventually faced with the decision of whether or not to train for a different career.

3.1.2. Problems of Dynamic Inconsistency and Risk Rigidities

The dynamic inconsistency problem stems from the fact that if the individual is to re-evaluate the maximization problem at the beginning of some future period (e.g., at the beginning of the work period), the original "lifetime plan" with respect to optimal risk acceptance is no longer optimal. The results here are similar to Robert Strotz's problem of consistent planning in his 1955 article entitled "Myopia and Inconsistency in Dynamic Utility maximization." Strotz showed that inconsistency arises if the individual discounts utility with a nonexponential discount function.

Strotz's result when applied to this model suggests that, unless the perceived risk of death is constant throughout an individual's life so that the odds of being alive decline exponentially over time, the "optimal" degree of job-related risk may be different when evaluated from some future

Figure 3.3: Hedonic Gradient and Indifference Curves for Risk Averse and Risk Loving Individuals



perspective. If people become more risk averse as they get older, the new optimal level of job-related risk of death will be lower. If this inconsistency is recognized, the individual can either retrain for a lower risk job or stay in the "high" risk job ("high" relative to what is now optimal). At some point in time the transaction costs of retraining and/or relocating will be too high relative to the benefits of shifting into an optimal risk job. Therefore the individual will be forced to stay in a "high risk" job.

Re-evaluating at the beginning of period two, this new problem is formulated as follows:

$$\max_{c_2,\, c_3,\, \hat{\pi}_2} E(U\ ) = (1-\pi_2)U_2(c_2) + (1-\pi_2)(1-\pi_3)U_3(c_3)$$

$$\text{subject to } WLTH(\hat{\pi}_2) - \bar{c}_1(1+r) = c_2 + \delta c_3$$

where: $\bar{c}_1$ = optimal consumption level from period one derived from the original maximization problem

The new first order conditions become:

$$\frac{\partial L}{\partial c_2} = (1-\pi_2)U'_2 - \lambda = 0 \tag{17}$$

$$\frac{\partial L}{\partial c_3} = (1-\pi_2)(1-\pi_3)U'_3 - \delta\lambda = 0 \tag{18}$$

$$\frac{\partial L}{\partial \hat{\pi}_2} = -U_2 - (1-\pi_3)U_2 + \lambda\frac{dWLTH}{d\hat{\pi}_2} = 0 \tag{19}$$

Conditions (17) and (18) again imply the standard utility maximization conditions put in expected utility terms like those derived above. Rewriting (19) we get:

$$WLTH'(\hat{\pi}_2) = \frac{(1-\pi_2)U_2 + (1-\pi_2)(1-\pi_3)U_3}{\lambda(1-\pi_2)} \tag{19'}$$

Where, once again, $WLTH'(\hat{\pi}\ )$, describes the slope of the hedonic wage-risk gradient. Following the same procedure as above to find MVS_2 we find that

$$MVS_2 = \frac{(1-\pi_2)U_2 + (1-\pi_2)(1-\pi_3)U_3}{\lambda(1-\pi_2)} \tag{20}$$

where MVS_2 is the individual's subjective evaluation of a reduction in $\hat{\pi}_2$ from a period two perspective. Conditions (19') and (20) imply that

$$WLTH'(\hat{\pi}_2) = MVS_2 \tag{21}$$

The optimal condition for risk in this problem (i.e., when evaluated at the beginning of period two) is similar to that in the above problem (i.e., when evaluated at the beginning of period one) in that they both describe a tangency between the hedonic gradient and the worker's indifference curve. However, the value for MVS has now changed.

The fact that living through period one is no longer uncertain gives the individual added information (i.e., that $\pi = 0$). Comparing (20) with with (15) we see that the difference between them is that condition (15) has the added term, $(1-\pi_1)$, multiplied to the numerator. Further, the value for λ is different because the maximization problem has changed. Since $0 < (1-\pi_1) < 1$, the numerator in (20) has increased from that in (15). However, the value for λ in (20) cannot be readily compared with the value for λ in (15) and, therefore, it cannot be determined from the calculus whether the denominator in (20) has increased or decreased from that in (15). On the other hand, there is no reason to believe, given these two changes, that MVS_1 equals MVS_2. If, however, individuals do in fact become more risk averse as they get older MVS_2 would be larger than MVS_1. If this is the case, the optimal level of risk derived at the beginning of period one is no longer optimal; in fact it is too high. Combining the tangency condition from (21) along with the fact that the individual's MVS has increased, suggests that their entire preference map has changed. Specifically, the individual now exhibits more risk-averse preferences (i.e., the indifference curves have become more steep).

Figure 3.4.1 represents this situation. $\hat{\pi}_2^*$ is the optimal level of risk when the individual evaluates the maximization problem at the beginning of period 1. $\hat{\pi}_2^{**}$, on the other hand, is the optimal level of risk when the individual re-evaluates the maximization problem at the beginning of period two. Note that Θ^* is a member of the old (less risk averse) preference map while Θ^{**} is a member of the new (more risk averse) preference map.

The costs of retraining for and shifting into a lower risk job are prohibitively high, the individual is locked into the "high risk" job, $\hat{\pi}_2^*$. Since the individual's indifference map is now changed, $\hat{\pi}_2^*$ is now associated with a point on an indifference curve such as Θ^{**} in Figure 3.4.2.

Figure 3.4.2 shows that the individual would like to be in a job with a risk level $\hat{\pi}_2^{**}$ which renders a maximum level of expected utility, Θ^{**}. However, since the person is locked into a job with risk $\hat{\pi}_2^{**}$ this person is at the sub-optimal level of utility, Θ^{**}. At $\hat{\pi}_2^{**}$ the slope of the hedonic wage gradient is less than the slope of the individuals indifference curve. That is, a "wedge" is placed between these two slopes. Therefore, if the hedonic approach is used to measure an individual's MVS (as interpreted by the slope of the hedonic wage gradient) this approach will underestimate peoples' true valuations of safety. The difference between these two slopes is the amount by which the hedonic approach underestimates an individual's MVS.

Figure 3.4.1: Indifference Map Between Wealth and Risk (1)

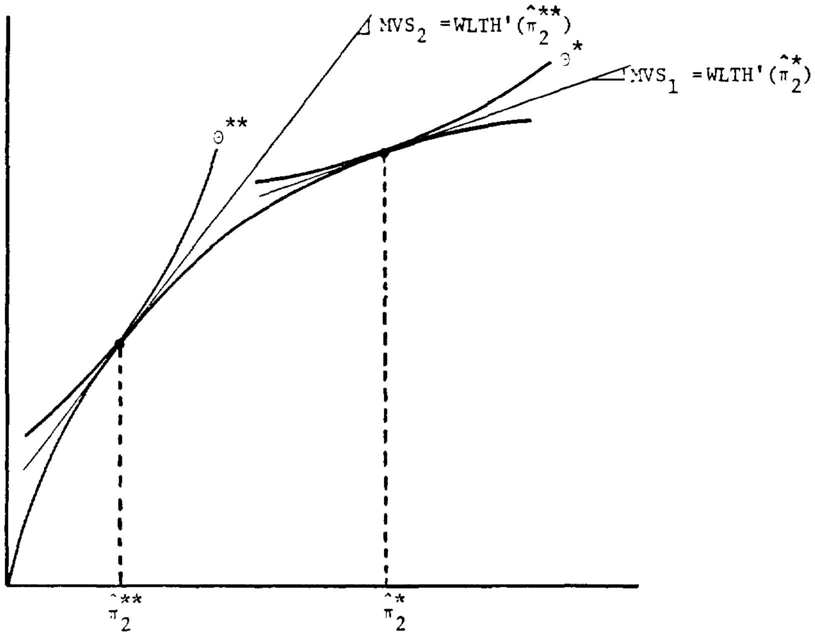
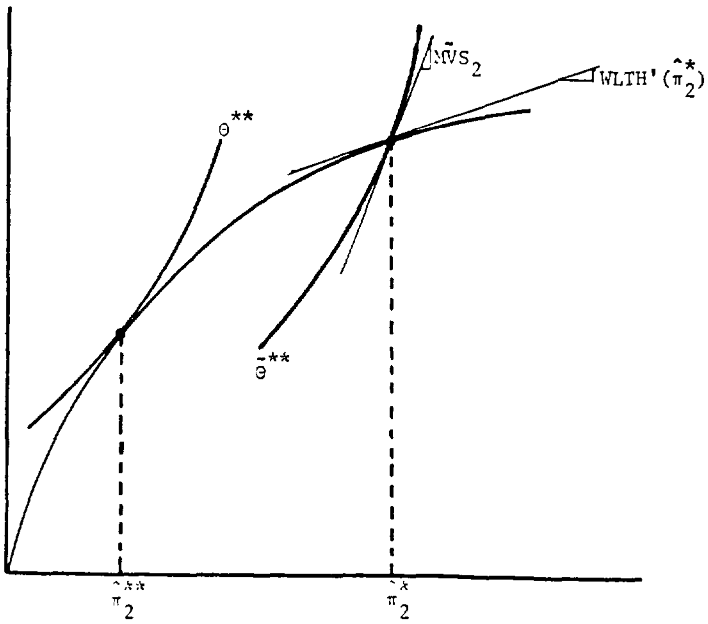


Figure 3.4.2: Indifference Map Between Wealth and Risk (2)



3.2 NON-SYMMETRIC CAPITAL MOBILITY

In the previous two sections a typical intertemporal budget constraint was employed wherein the interest rate at which an individual can borrow on future earnings was identical to the rate earned on savings. Once this assumption is dropped, however, the results of the model presented above are changed and another "wedge" between the slope of the hedonic wage gradient and an individual's MVS is rendered.

The budget constraint employed here takes into account that the interest rate on borrowed funds, r_b, may well differ from the rate on savings, r_s; the former taking into account the risk that the individual may not survive to pay back the loan.

Recall that the intertemporal budget constraint used above, re-written, was in the form:

$$\frac{WLTH(\hat{\pi}_2)}{\delta} = (1 + r)c_1 + c_2 + \frac{c_3}{(1 + r)} \tag{22}$$

If we assume that the real rate of interest which the individual can borrow on future earnings, r_b, differs from the real rate of interest on savings, r_S, equation (21) is modified as

$$\frac{WLTH(\hat{\pi}_2)}{\delta} = (1 + r_b)c_1 + c_2 + \frac{c_3}{(1 + r_s)} \tag{23}$$

It will be assumed, however, that there exist some relationship between r_b and r_S and that $r_b \geq r_s$. Specifically the assumption is made that:

$$(1 + r_b) = \gamma(1 + r_s) \tag{24}$$

where $1 < \gamma < \infty$.

In the above life cycle model the individual borrows on future earnings in order to finance consumption during his training period. Depending on the specific job the individual is training for, the risk associated with his particular job will affect the probability that he will live to pay back the loan. While r_b is influenced by other job-related factors, as well as non-job-related factors, it is reasonable to assume that r_b will increase, ceteris paribus, with the risk level of the job the individual is training for, specifically,

$$\gamma = \gamma(\hat{\pi}_2) \tag{25}$$

where $\gamma' > 0$.

Assuming that money is discounted at the opportunity cost of savings, equation (22) can now be re-written as:

$$WLTH(\hat{\pi}_2) = \gamma(\hat{\pi}_2)c_1 + \delta c_2 + \delta^2 c_3 \tag{26}$$

where $\delta = 1/(1 + r_s)$. The individual's beginning of the first period maximization problem now becomes:

$$\max_{c_1,\, c_2,\, c_3,\, \hat{\pi}_2} \quad E(U^L)$$

$$\text{subject to: } WLTH(\hat{\pi}_2) = \gamma(\hat{\pi}_2)c_1 + \delta c_2 + \delta^2 c_3$$

From the first order conditions the optimal level of job-related risk is described by the condition:

$$WLTH'(\hat{\pi}_2) = MVS_1 - \gamma' c_1 \tag{27}$$

where again the left hand side of (27) is the slope of the hedonic wage gradient.

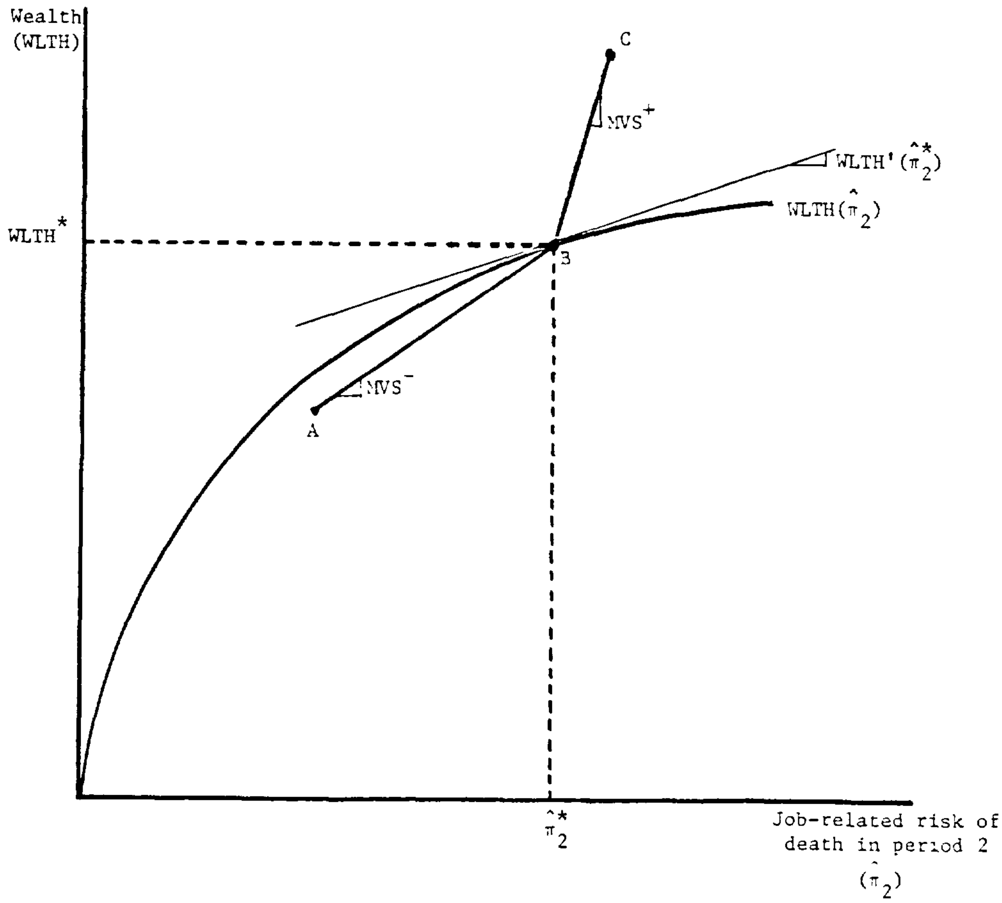
From equation (27) it is clear that the rate of which the market compensates the worker does not equal his subjective MVS: specifically, $WLTH'(\pi) < MVS_1$. Therefore in this situation hedonic wage-risk studies would underestimate workers' true evaluations of risk reduction.

3.3 HEDONIC ESTIMATES AND WTP VS. WTA

The theoretical model presented above offers two reasons why one might expect, a priori, hedonic estimates of valuations of an expected life saved to underestimate the "true" subjective MVS measure. This hypothesis is tested in Chapter 5. Further the theoretical results in Section 2.4 suggest another testable hypothesis that WTA measures should exceed WTP measures of the MVS: The difference being explained by individual's conservative tendency to overestimate losses in wealth and underestimate gains in wealth.

These two theoretical results are brought together here and are shown in Figure 3.5. This figure shows the hedonic wage gradient, $WLTH(\pi_2)$, as intersecting the worker-consumer's indifference curve, ABC as suggested by the results in Sections 3.1 and 3.2. For illustrative purposes, the curve ABC has been linearized about the initial (optimal) levels of job-related risk of death and wealth, $\hat{\pi}_2^*$ and WLTH* respectively. Similar to the curve, ABC has a steep segment, BC (which corresponds to the individual underestimating gains in wealth), and a flat segment, AB (which corresponds to the individual overestimating losses in wealth). Further, the slope of AB, MVS^-, corresponds to the subjective MVS for a reduction in period two's job-related risk of death (i.e., WTP) while the slope of BC, MVS^+, corresponds to the subjective MVS for an increase in such risk (i.e., WTA). This figure suggests that, while estimates from hedonic wage-risk studies underestimate an individual's true MVS (since MVS^+ 7 MVS^- 7 $WLTH'(\hat{\pi}_2^*)$), these studies may yield estimates which are statistically similar for WTP measures (since $MVS^{-} - WLTH'(\hat{\pi}_2^*)$ is relatively small). On the other hand one would expect hedonic estimates to grossly underestimate true WTA measures of the MVS (since $MVS^{+} - WLTH'(\hat{\pi}_2^*)$ is relatively large). These hypotheses are tested in Chapter 5.

Figure 3.5: Hedonic Wealth-Risk Gradient



CHAPTER 4
SURVEY METHODOLOGY

4.1 OVERVIEW

The data analyzed in this report are drawn from a national mail survey conducted in the summer of 1984. The data collected measure

(1) individual perceptions of respondents job-related risk of death,

(2) willingness to pay and willingness to accept measures for hypothetical changes in these risks (i.e., the contingent valuation), and

(3) all socio-economic earnings, hours, work place, and human capital characteristics needed for estimating a hedonic wage equation.

The intertemporal expected utility model developed in chapter three would suggest that the market does not correctly compensate individuals for the risk they face on the job. Hence, the hypothesis is that standard hedonic wage-risk models fail to accurately measure marginal value of safety. A comparison of the contingent valuation method for measuring marginal value of safety with the hedonic wage equation derived from the same subjects provides a test for this hypothesis.

The decision to conduct a mail survey (rather than face-to-face interviews) was determined primarily by cost. The mail survey is less expensive by at least a factor of ten, however, there are difficulties associated with mail surveys. The type of information required for this study is difficult for the respondent to fully understand, and the quantity of information needed was large. Both of these factors would tend to decrease response rates and the reliability of responses. For these reasons every possible effort was made to implement the best possible survey techniques to minimize these effects. In fact, a secondary objective of this study is to test whether complex data of this type can be obtained via a mail survey.

Since both willingness to pay and willingness to accept measures of individuals' marginal values of safety were sought, two forms of the questionnaire were developed. These two forms were identical except for the one contingent valuation question, and the language used to ask these two questions were made as similar as possible. Both forms of this question are presented in Appendix A.

The total design method for mail surveys, as discussed in Dillman (1978), was used for this study. This method includes the design of the questionnaire, the procedures for mailing the questionnaires, and all follow-up procedures. Dr. Dillman served as a consultant to this project to further insure quality survey technique.

4.2 QUESTIONNAIRE DEVELOPMENT

The form of the questionnaire is of critical importance in any mail survey. It must be attractive in appearance, the information needed by the respondents must be clearly worded, the questions and response categories must be clearly stated, and there should be a natural flow which encourages the respondent to complete all the questions. Most of all, the questions must be carefully worded to avoid any bias in response. The length of the questionnaire is also important; and any more than ten pages often results in significant reduction in response rates.

A complete list of information required for the study objectives was compiled, and tentative question formats were prepared. In this process, the researchers were guided by an extensive review of the literature and other surveys dealing with estimating the marginal value of safety. A maximum length of ten pages was set. Several revisions of the individual questions and order of questions were made. General principles guiding this development include:

- The early questions should be simple, applicable to all respondents, interesting, and a sense of neutrality should be conveyed.
- Questions should be ordered along a descending gradient of importance, and questions with similar content should be grouped together.
- Questions which might be objectionable to most respondents should be placed after less objectionable ones.

The questionnaire form was a booklet made from 8½" x 12¼" sheets. The cover contained the study title, a graphic illustration related to risk, name and address of study group, and directions as to who should answer the questionnaire. The back page had only an invitation for additional comments, a thank you, and an offer to send results of the study. Lower case letters were reserved for questions and upper case for answers. Answer categories were identified on the left with numbers, and a vertical flow was established throughout. Some graphics were used to explain concepts, such as risk of death, and to identify question flow.

Three methods were used to pretest the questionnaire. The purpose of the pretesting was to uncover any problems in wording or format that would be difficult for the respondent to understand or would result in bias in the answer. The first pretest involved several persons on the University of Wyoming campus knowledgeable about survey design and/or the area of risk, for example the University safety officer completed the questionnaire and made comments relative to wording and completeness. The second pretest involved 30 University employees in buildings and grounds. Their occupations were in construction, clerical, mechanics, grounds keepers, and maintenance. The final pretest involved mailing 250 questionnaires to 250 households randomly selected from the Denver, Colorado Springs, and Pueblo phone books. Researchers pursuing other related research projects funded by current USEPA cooperative agreements also reviewed the questionnaire. Responses to questions and comments made on all three of these pretests were incorporated into the final form of the questionnaire.

Dr. Don Dillman, acknowledged expert on sample survey design and founder of the total design method, was employed as consultant to review the questionnaire. This review resulted in a number of improvements in the form, particularly in terms of the graphics used and explanation of risk concepts. Copies of the final questionnaire form are found in Appendix A.

4.3 SAMPLE DESIGN

Two conditions imposed on the sample design were that: (1) it be national in scope and (2) efforts be made to insure adequate response in the high risk categories. It was also recognized that persons unemployed, retired, part-time worker only, self-employed, or for whom a substantial portion of their income was made up of government assistance would not be useful respondents. (This point is treated more fully in Chapter 5). Therefore, some deliberate over sampling was required to insure an adequate number of useable responses.

The first component of the sample consisted of a simple random sample of 3,000 households from the entire United States. The second component was more complex. Four regions, Northeast, South, West, and North Central were identified. States within each of the four regions that were known to have concentrations of high risk industries (lumbering, mining, oil, steel mills, construction, heavy industry, etc.) were selected. Within these states, counties with highest concentrations of these industries were selected (a total of 105 counties). Finally, 750 households were randomly drawn from the selected counties in each of the four regions. Thus, the second part of the sample consisted of 3,000 households randomly selected from 105 counties known to have high concentrations of high risk industries. Tables 4.2 and 4.3 contain a summary comparison of the demographic characteristics of these two samples.

The actual sample was generated by Survey Sampling, Inc., 180 Post Road East, Westport, CT 06880. This firm maintains and regularly updates computer tapes of census data, and they have the capability of generating random samples from a wide variety of specifications. In particular, they were able to generate one national random sample of size 3,000, and random samples of size 750 each from the four lists of counties we provided. Their updating of files is such that they guarantee less than 15 percent of the addresses undeliverable. In our study, that figure was about 12 percent.

4.4 SURVEY PROCEDURES

On Monday, July 9, all 6,000 households in the sample were mailed a cover letter, a copy of the questionnaire, and a stamped return envelope. The cover letters were individually addressed, typed on monarch stationery, and hand-signed in blue ink. This letter was designed to explain the nature and usefulness of the study, that all respondents are important, and to assure confidentiality (see copy in Appendix B). An identification number was stamped on each questionnaire for follow-up procedures. Each of the two samples of 3,000 were ordered by zip code. Willingness to pay and willingness to accept questionnaires were alternated through the samples.

Eight days after the initial mailing, July 16, post cards were sent to all persons in the sample. The first follow-up was designed as a thank you and a reminder, the post card included the mail-out date and an individual signature in blue ink of the project director. The person's name and address was typed on the card as opposed to mailing labels. A copy of the post card is given in Appendix C.

Twenty-two days after the original mail-out, July 30, a second follow-up consisting of a replacement questionnaire, a stamped return envelope, and a cover letter were sent to everyone who had not yet responded. This cover letter, also individually typed and signed, was designed to encourage the respondent to complete and return the questionnaire (see copy in Appendix D). No further follow-ups were planned or implemented, however, the total design method does include one more by certified mail or phone.

4.5 RESPONSE RATES

Of the 6,000 questionnaires mailed, 749 (12.5 percent) were returned by the post office as undeliverable. A total of 2,103 were returned complete for a response rate of 40 percent of delivered or 35 percent of total mailed. Of these returns, only 1,231 were employed and therefore useable in this study. Thus the actual useable returns are only 20.5 percent of the original mailing, or 23.4 percent of those delivered. Figure 4.1 is a graphical display of the responses by time from the first mailing.

The motivation for splitting the sample was to obtain more responses from individuals in high risk jobs. Table 4.1 gives the numbers in each (perceived) risk category for the two samples. The sample from selected counties did in fact have significantly more ($\alpha = .037$) respondents in higher risk categories, however the difference in actual numbers is not great. For example, there were only 31 more respondents from the random sample of selected counties in the risk categories 6 through 10 as compared to the simple random sample. This is a difference of 15 percent compared to 9.5 percent.

Table 4.2 contains a comparison of job related characteristics between the national random sample and the random sample drawn from selected

FIGURE 4.1 CUMULATIVE RESPONSES BY DAY

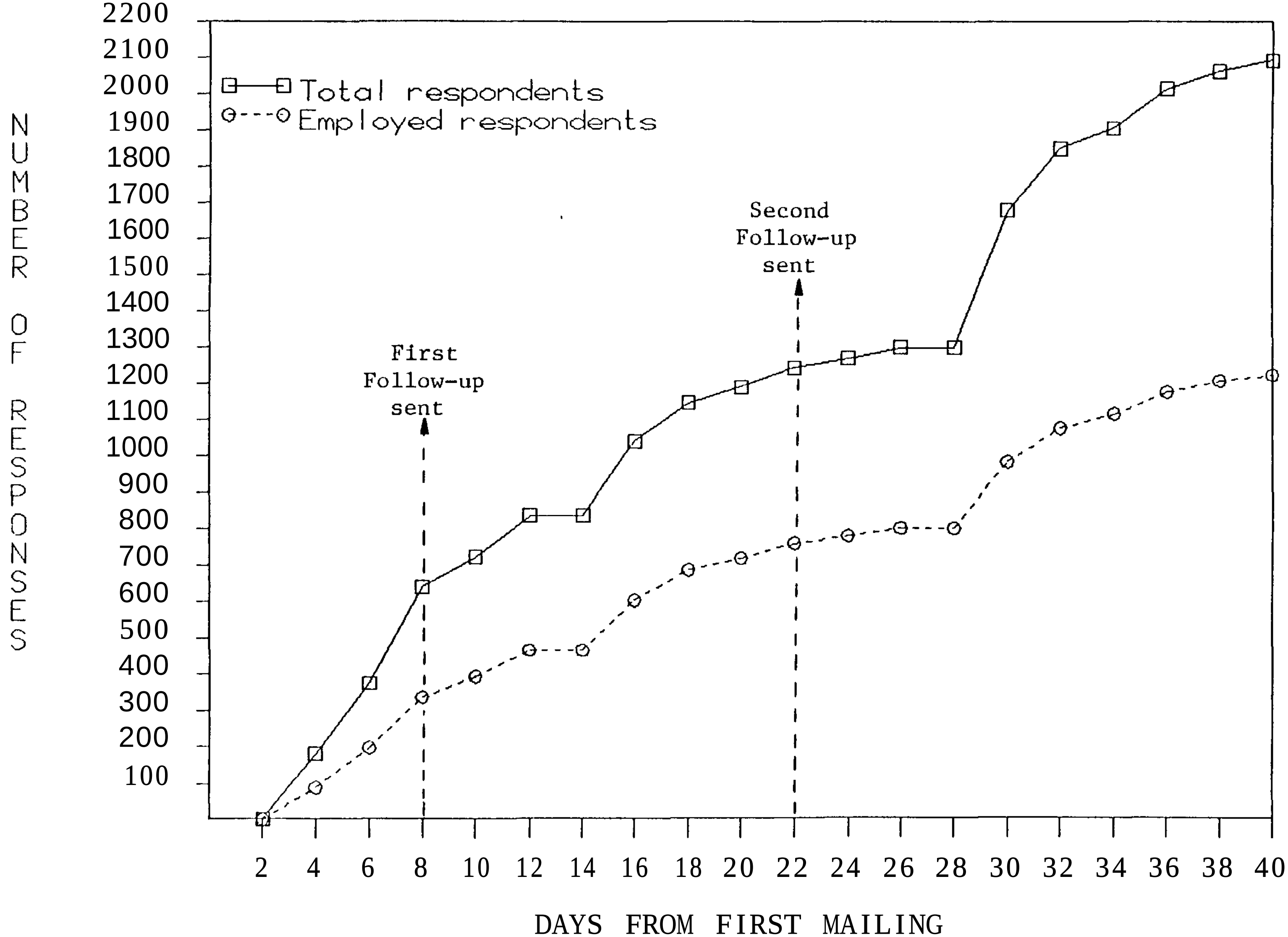


TABLE 4.1: LEVEL OF RISK

Sample Type	12	3	4	5	6	7	8	9	10	Total
National Random	285	72	58	41	39	21	8	13	6	7	572
Random from Selected Counties	244	81	71	36	37	26	23	23	3	11	575
Total	529	153	129	77	76	74	31	36	9	18	1147

Number of missing values = 71
Completed returns not in this run = 84.

counties. The p values listed are for the tests of the null hypothesis that the two populations are the same. None of these job characteristics were significantly different at the .05 level of significance. The three that were significant at the .10 level were the level education required for the job, whether or not special training was needed, and the type of special training needed. It was interesting that occupation classification was not significantly different even though that characteristic is more directly related to the selection of counties.

Table 4.3 contains a similar comparison for personal characteristics of the respondents. The only two that show significant differences were type of living area and type of work area. This is to be expected since property is directly related to the counties selected and the fact that samples of equal size were drawn from the four regions of the United States. None of the other personal characteristics were anywhere near significant.

The similarity of the two samples with respect to demographic characteristics would tend to indicate that weighted regression estimates will be almost identical to unweighted. Further analysis will be completed using weighted regressions to either confirm or contradict this statement, and these results will appear in the final draft. Further analysis will also consider regional differences in the wage equation as well as the impact of air pollution measures.

The actual cost for completing the data collection for this study was approximately $14.00 per completed questionnaire, or nearly five dollars for each sampled household. This figure does not include the time of principal investigators directly related to the questionnaire design, the sample design, and data preparation. It also does not include such activities as the theoretical formulation of the problem, the analysis and interpretation of the data, and the writing of reports and research papers. Face-to-face interviews for a study of this type would likely be in excess of $100.00 per completed interview, exclusive of transportation costs which would be enormous for a national sample.

TABLE 4.2: COMPARISON OF JOB CHARACTERISTICS FOR NATIONAL AND SELECTED COUNTIES RANDOM SAMPLES

Characteristics	National Random Sample	Selected Random Sample	p value
Occupation Type:			
Service Worker	8.7	8.0	.286
Laborer	6.6	8.7	
Transportation Operator	3.3	4.8	
Equipment Operator	4.2	5.8	
Craft Worker	15.5	16.6	
Clerical Worker	6.1	5.3	
Sales Worker	6.3	7.3	
Manager or Administrator	16.3	12.8	
Professional or Technical	31.1	29.9	
Farmworker	1.9	.9	
Education Required for the Job:			
0-8 Grades	4.9	4.5	0.63
6-9 Grades; Finish Grade School	1.4	2.1	
9-11 Grades; Some High School	4.5	6.3	
12 Grades; Finish High School	31.6	34.1	
Some College, No Degree Necessary	19.4	19.3	
College Degree; BA or BS	25.9	18.1	
Some Graduate Work	3.3	4.7	
Advanced College Degree or Professional Degree	8.9	11.0	
Special Training Needed for the Job:			
Yes	80.6	84.8	0.61
No	19.4	15.2	
Type of Training Needed for the Job:			
None	17.1	15.1	.097
Apprenticeship	5.0	7.4	
Vocational Trade School	3.2	2.9	
On-The-Job Training	29.3	30.6	
Work Experience from Another Job	22.9	17.6	
Other	22.6	26.3	

(continued)

Table 4.2, continued

Characteristics	National Random Sample	Selected Random Sample	p value
Type of Employment:			
Self Employed	15.9	16.5	.626
Government	17.0	17.9	
Other	67.1	65.6	
Do You Supervise Others:			
Yes	59.4	60.4	.719
No	40.6	39.6	
Is Your Job Covered by a Union Contract:			
Yes (Member)	24.7	30.5	
Yes (Not Member)	4.9	5.8	
No	70.5	63.7	
Way Paid:			
Salary	50.8	46.9	.296
Hourly Wage	37.2	41.7	
Other	12.0	11.4	
Number of Years Training Needed	3.32	3.51	.399
Years Worked for Current Employer	11.39	12.09	.231
Years this Type of Work	13.18	13.79	.320
Number Employed where You Work	669.41	588.93	.355

TABLE 4.3: COMPARISON OF PERSONAL CHARACTERISTICS FOR NATIONAL AND SELECTED COUNTIES RANDOM SAMPLES

Characteristics	National Random Sample	Selected Random Sample	p value
Sex:			
Male	82.7	85.2	.249
Female	17.3	14.8	
Race:			
White	93.2	95.4	
Nonwhite	6.8	4.6	
Education:			
0-5 Grades	.5	.5	.387
6-8 Grades; Finished Grade School	1.7	3.6	
9-11 Grades; Some High School	4.2	5.1	
12 Grades; Finished High School	9.6	20.9	
Trade School	8.8	6.3	
Some College	24.3	25.1	
College Degree; BA or BS	19.2	16.2	
Some Graduate Work	7.5	7.5	
Advanced College Degree or Professional Degree			
Living Area Type:			
Rural	26.0	34.7	.005
Suburban	56.0	49.8	
Central City	18.0	15.5	
Work Area Type:			
Rural	21.8	31.0	.001
Suburban	38.0	36.1	
Central City	40.2	32.9	

(continued)

Table 4.3, continued

Characteristics	National Random Sample	Selected Random Sample	p value
Veteran:			
Yes	39.0	38.3	.802
No	61.0	61.7	
Age:			
Mean	42.15	42.60	.533
Years Worked Since 18:			
Full or Part Time	22.49	22.72	.739
Full Time	20.91	21.13	.759

CHAPTER 5

EMPIRICAL MARGINAL VALUE OF SAFETY ESTIMATES

Empirical estimates of the marginal value of safety (MVS) from both hedonic studies and contingent valuation studies have been summarized in the economics literature (e.g. Violette and Chestnut, 1983). As a result, there may be a natural inclination to compare the safety valuations implied by these two methods. However, the MVS estimates from studies which utilize the hedonic technique are not directly comparable to those derived from contingent valuation studies primarily because different measures of risk, as well as different types of risk, are employed. As a result the two approaches can not be directly compared.

In Chapter 4 a particular survey design was described whose goal was to directly compare the hedonic and contingent valuation approaches. Information was obtained from each respondent which rendered two separate MVS estimates: one from an estimated hedonic wage-risk equation and another through a contingent valuation process. Since both procedures utilized the same risk measure (perceived job-related risk of death and data set, some insight on how one technique compares to the other can be drawn. Moreover, since each respondent was directly asked the perceptions of his specific occupation, the type of error in variables problems mentioned in chapter two are presumed to be circumvented.

The remainder of this chapter is organized as follows: in Section 5.1 the hedonic wage equation to be estimated is specified with the empirical results reported in Section 5.2. Section 5.3 compares the MVS measures obtained from both the hedonic wage equation and the contingent valuation with the resulting implications and conclusions in Section 5.4.

5.1 SPECIFICATION OF THE WAGE EQUATION

The general form of the hedonic wage equation considered here is based on that used by Gerking and Weirick (1983) and is in the following form:

$$LWAGE = f(H, P, W) \tag{1}$$

where LWAGE denotes the natural logarithm of the wage rate paid, H denotes a vector of human capital variables, P denotes a vector of personal characteristics, and W denotes a vector of work environmental variables. The natural logarithm of the wage rate is employed in order to compensate for the non-normal distribution of income. By forcing the distribution of income to be roughly normal, equation (1) can be estimated via an ordinary least squares (OLS) procedure. Further, the vectors H, P. and W pertain to the household head, and his or her primary job in 1983, from families across the entire United States. Further, the wage rate paid, WAGE, was adjusted for regional price differences.

Within equation (1) the vector H measures: (1) the highest level of formal schooling completed (CED), (2) years worked in the present occupation (YWO), (3) years of full time work experience (WEXP), and (4) years worked for present employer (YREMP).

Personal characteristics, P, are described by measurements on : (1) age (AGE), (2) race (RACE), (3) sex (SEX), (4) physical limitations or disabilities (PHYS), (5) whether or not the household head has moved in the last three years (MOVE), and (6) whether or not the individual lives in a rural area (LIVEA).

The vector W measures: (1) the individual's perceived level of job-related risk (RISK), (2) the highest level of formal schooling required to work on the present job (RED), (3) the number of people the individual supervises (SUP), (4) whether or not the individual works in the public sector (PUB), (5) whether or not some work experience or special training is required to get a job like the present one (REXP), (6) union membership (UNI), (7) years required for the average new person to become fully qualified in the head's present job (QUAL), (8) the type of occupation the individual is employed in (OCC), (9) miles traveled from the head's home to his job (DIST), (10) whether or not the job is located in a rural area (JOBA), and (11) the number of people employed at the head's work (NUM).

While the variables contained in vectors H, P, and W are expected to explain variations in the wage rate, cross effects between some variables might also be expected to be significant. Since this research effort concentrates on risk, the following cross terms are analyzed: (1) risk with age (RXAGE), (2) risk with union status (RXUNI), (3) risk with sex (RXSEX), and (4) risk with race (RXRACE).

Similar cross terms to those described above have been employed in other hedonic wage-risk studies (e.g., Thaler and Rosen, 1975; Viscusi, 1978a; Olson, 1981). In this study, both RXSEX and RXRACE were continually found to be highly insignificant; therefore, only RXAGE and RXUNI were included in the final estimate wage equation.

Exact descriptions for these data are contained in Table 5.1 with their sample means reported in Table 5.2. Further, all the variables above were obtained from the survey described in chapter four (see Appendix A).

Before equation (1) was estimated, a few theoretical problems in using the complete data set had to be addressed. Gerking and Weirick (1983) note that households which receive a significant percentage of their income in the form of transfer payments face non-convex budget constraints. To

TABLE 5.1
VARIABLE DEFINITIONS

A. DEPENDENT VARIABLE

WAGE = (Head's average hourly wage rate from primary job)[1]

LWAGE = In (WAGE)

B. HUMAN CAPITAL VARIABLES

CED1 = 1 if (CED) = 0 to 5 grades, otherwise = 0

CED2 = 1 if (CED) = finished grade school, otherwise = 0

CED3 = 1 if (CED) = some high school, otherwise = 0

CED4 = 1 if (CED) = finished high school, otherwise = 0

CED5 = 1 if (CED) = finished high school and some trade school, otherwise = 0

CED6 = 1 if (CED) = some college, otherwise = 0

CED7 = 1 if (CED) = college degree; BA or BS, otherwise = 0

LEDB = 1 if (CED) = some graduate work, otherwise = 0.[2]

YWO = (Years worked in present occupation)

WEXP = (Years of full time work experience)

YREMP = (Years worked for present employer)

C. PERSONAL CHARACTERISTIC VARIABLES

AGE = (Age in years)

RACE = 1 if white, otherwise = 0

SEX = 1 if male, otherwise = 0

PHYS = 1 the individual has any physical or nervous conditions that would limit the type or amount of work he could do, otherwise = 0

MOVE = 1 if the individual has moved in the last three years, otherwise = 0

LIVEA = 1 if the individual lives in a rural area, otherwise = 0

(continued)

Table 5.1 (continued)

D. WORK ENVIRONMENT VARIABLES

RISK = (the individuals perceived level of job-related risk of death) Risk takes on an integer value from 1 (one job-related death per year per 4,000 workers in the individual's occupation) to 10 (ten job-related deaths per year per 4,000)

RED1 = 1 if (RED) = 1 to 8 grades, otherwise = 0

RED2 = 1 if (RED) = finish grade school, otherwise = 0

RED3 = 1 if (RED) = some high school, otherwise = 0

RED4 = 1 if (RED) = some college; no degree necessary, otherwise = 0

RED5 = 1 if (RED) = some college; no degree necessary, otherwise = 0

RED6 = 1 if (RED) = college degree; BA or BS, otherwise = 0

RED7 = 1 if (RED) = some graduate work, otherwise = 0.[3]

SUP = (the number of people the individual supervises)

PUB = 1 if the individual is employed in the public section, otherwise = 0

REXP = 1 if some work experience or special training is required to get a job like the individual's, otherwise = 0

UNI = 1 if the individual has a union contract, otherwise = 0

QUAL = (the number of years it would take the average person to become fully trained and qualified on the present job)

OCC1 = 1 if (OCC) = service worker, otherwise = 0

OCC2 = 1 if (OCC) = laborer, otherwise = 0

OCC3 = 1 if OCC = transportation operator, otherwise = 0

OCC4 = 1 if (OCC) = equipment operator, otherwise = 0

OCC5 = 1 if (OCC) = craft worker, otherwise = 0

OCC6 = 1 if (OCC) = clerical worker, otherwise = 0

OCC7 = 1 if (OCC) = sales worker, otherwise = 0

(continued)

Table 5.1 (continued)

OCC8 = 1 if (OCC) = manager or administrator, otherwise = 0[4]

OCC9 = 1 if (OCC) - farmer, otherwise = 0

NUM = (the number of people employed at the head's workplace)

DIST = (the miles from the individual's home to his work)

JOBA = 1 if the job is located in a rural area, otherwise = 0

E. CROSS TERMS

RXUNI = (RISK) x (UNI)

RXAGE = (RISK) x (AGE)

TABLE 5.2: MEANS AND STANDARD DEVIATIONS OF VARIABLES MEASURED

Variable	Mean	Standard Error
LWAGE	2.411	.017
CED1	.007	.003
CED2	.020	.005
CED3	.048	.007
CED4	.213	.014
CED5	.076	.009
CED6	.244	.015
CED7	.183	.014
YWO	12.509	.336
WEXP	20.650	.412
YREMP	11.838	.341
AGE	41.595	.403
RACE	.945	.008
SEX	.837	.013
PHYS	.115	.014
MOVE	.220	.015
LIVEA	.331	.016
RISK	2.605	.075
RED1	.029	.006
RED2	.010	.003
RED3	.050	.008
RED4	.362	.017
RED5	.191	.014
RED6	.227	.015
RED7	.042	.007
SUP	13.637	2.606
PUB	.212	.014
REXP	.839	.013
UN1	.390	.017
QUAL	3.215	.115
OCC1	.091	.010
OCC2	.069	.009
OCC3	.037	.007
OCC4	.059	.008
OCC5	.164	.013
OCC6	.058	.008
OCC7	.050	.008
OCC8	.150	.013
OCC9	.004	.002
DIST	11.625	.470
JOBA	.246	.015
RXUNI	.255	.054
RXAGE	-23.537	114.096

circumvent this problem, those household heads which received more than 20 percent of their total income from transfer payments were eliminated from the sample. Further, Gerking and Weirick state that "casual workers ... may be out of equilibrium because their asking wage may exceed their offered wage." In light of this potential problem, those household heads who worked less than 1,250 hours in 1983 were also eliminated from the sample.

In addition to these two sets of exclusions, individuals who were self-employed were also eliminated from the data set. The justification for this centers around the difficulty these individuals might have in estimating their total number of 1983 working hours. Without a reliable measure for hours, an accurate wage rate cannot be imputed for those who are self-employed.

As is usually the case with large data sets, missing values were present in the original data. A reasonable method commonly employed in econometric studies is to assign means (for continuous variables) and modes (for discrete variables) in situations where an observation on a particular variable is missing. This method was employed in this study except for the risk, wage, and occupation variables. Since an individual's wage rate is the variable which equation (1) is attempting to explain, it was felt that substituting the mean for WAGE in situations where this variable was missing would be inappropriate. Consequently, individuals who did not report their 1983 wage were eliminated from the data set.

With respect to risk, another method was employed to deal with missing values. This procedure entailed regressing perceived risk on occupation for the subset of total respondents who gave information on these two variables. Then, this regression equation was utilized for the purpose of predicting a perceived risk measure for those individuals who did not report such a measure. By doing this, it was felt that a more accurate representation of their perceived risk would be rendered than if merely the mean of RISK was used. Of course for the few people who did not report an occupation (this amounted to 12 observations) this could not be done; therefore, these observations were eliminated from the data set.

With respect to the variables in which a mean or mode was assigned to a missing value, the total number of these cases was not significant. Depending on the particular variable, and after the above sets of exclusions were made, missing values ranged from 0 to 20. Further, after the above sets of exclusions were made, the data set was reduced from 1,351 observations originally available from the survey to 888. Therefore, at worst, the number of missing values for any specific variable amounted to only 2 percent of the final data set.

5.2 EMPIRICAL ESTIMATES

The exact specification of equation (1) is shown in Table 5.3 along with the resulting ordinary least squares (OLS) estimates. Because the dependent variable is in logarithmic form, the coefficients are interpreted

TABLE 5.3: REGRESSION RESULTS

Dependent Variable:	LWAGE
Number of Observations:	888
Sum of Squared Residuals:	105.54
R-Squared:	.495
Adjusted R-Squared:	.464

Explanatory Variable	Coefficient	Standard Error	t-Statistic
CED1	-.277 E-0	.166 E-0	-1.665
CED2	-.342 E-0	.115 E-0	-2.951
CED3	-.264 E-0	.852 E-1	-3.101
CED4	-.204 E-0	.653 E-1	-3.129
CED5	-.153 E-0	.721 E-1	-2.116
CED6	-.129 E-0	.608 E-1	-2.138
CED7	-.631 E-1	.564 E-1	-1.118
CED8	.115 E-0	.659 E-1	1.750
YWO	.369 E-2	.274 E-2	1.346
YWO**2	-.318 E-3	.158 E-3	-2.022
WEXP	.106 E-1	.310 E-2	3.403
WEXP**2	-.189 E-3	.786 E-4	-2.411
YREMP	.103 E-1	.229 E-2	4.462
YREMP**2	-.187 E-3	.126 E-3	-1.485
AGE	-.518 E-2	.298 E-2	-1.740
RACE	.577 E-1	.577 E-1	1.115
SEX	.177 E-0	.375 E-1	4.725
PHYS	-.474 E-1	.313 E-1	-1.512
MOVE	-.592 E-1	.316 E-1	-1.875
LIVEA	-.885 E-1	.301 E-1	-2.946
RISK	.756 E-1	.270 E-1	2.799
RISK**2	-.667 E-2	.259 E-2	-2.577
RXAGE	-.147 E-2	.579 E-3	-2.542
RXUNI	.273 E-1	.119 E-1	2.287
RED 1	-.323 E-0	.107 E-0	-3.004
RED2	-.274 E-0	.139 E-0	-1.966
RED3	-.276 E-0	.912 E-1	-3.030
RED4	-.228 E-0	.745 E-1	-3.025
RED5	-.202 E-0	.712 E-1	-2.836
RED6	-.879 E-1	.614 E-1	-1.434
RED 7	-.162 E-1	.814 E-1	-1.993

(continued)

Table 5.3 (continued)

Explanatory Variable	Coefficient	Standard Error	t-Statistic
SUP	.353 E-3	.174 E-3	2.027
PUB	-.502 E-1	.328 E-1	-1.529
REXP	.745 E-1	.356 E-1	2.090
UNI	.867 E-1	.293 E-1	2.965
NUM	.189 E-4	.835 E-5	2.259
QUAL	.184 E-1	.434 E-2	4.240
OCC1	-.194 E-0	.556 E-1	-3.491
OCC2	-.261 E-1	.643 E-1	- .406
OCC3	-.10l E-0	.781 E-1	-1.295
OCC4	-.619 E-1	.659 E-1	- .941
OCC5	-.104 E-0	.496 E-1	-2.098
OCC6	-.149 E-0	.647 E-1	-2.303
OCC7	-.974 E-1	.594 E-1	-1.640
OCC8	.332 E-1	.407 E-1	.813
OCC9	-.549 E-0	.186 E-0	-2.957
DIST	.275 E-2	.950 E-3	2.895
JOBA	-.660 E-1	.321 E-1	-2.057
CONSTANT	.244 E+1	.166 E-0	14.745

in percentage terms. For example, the coefficient on YREMP suggests that for an additional year of seniority, an individual is rewarded with a one percent increase in his wage rate. It should be noted, however, that the coefficients on the dummy variables lack this straightforward interpretation.

As described in Chapter 4 the data were made up of two separate sample spaces, both being random. Therefore, a chow-test was constructed in order to see if the two samples could be pooled. The results of this test are shown in Table 5.4. E_1 denotes the statistics from estimating equation (1) and using the national sample; E_2 using the selected, high risk, counties sample; and E_R using both samples. The computed F-statistic was .95, suggesting that the two samples could be pooled.

The results in Table 5.3 show that the estimated coefficients have the signs one would expect and most are significant. For example, individuals who live or work in rural areas or who work in the public sector receive a lower wage rate, ceteris paribus - as suggested by the negative coefficients on LIVEA, JOBA, and PUB respectively. The positive coefficients on WEXP and QUAL suggest, respectively, that those individuals with relatively more years of full-time work experience, or for jobs which require relatively more time for the average person to become fully qualified, wage rates are higher. The negative coefficients on YWO**2, YREMP**2 and WEXP**2 denote that there exists diminishing returns to occupational experience, seniority, and full-time work experience. Further, the coefficients on RED1 through RED2 illustrate that as less formal schooling is required for an occupation, wages are penalized at an increasing rate.

Such influences on wages are typically included in wage equations. However, since the goal of this research is to derive a marginal value of safety, the risk variables are of primary concern. The variables of interest are, therefore, RISK, RISK**2, RXAGE, and RXUNI.

Thaler and Rosen (1975) were the first to note the positive relationship between risk and wages; that is:

$$\frac{\partial WAGE}{\partial RISK} > 0 \qquad (2)$$

To derive an expression like equation (2) consider the following representation of the above estimated hedonic wage equation:

$$LWAGE = \alpha o + \alpha Z + \beta_1 \, RISK + \beta_2 (RISK)^2 + \beta_3 RXAGE + \beta_4 RXUNI \qquad (3)$$

where Z ≡ a vector containing all other variables specified in equation (1). Exponentiating both sides of (3) and then differentiating with respect to risk yields:

$$\frac{\partial WAGE}{\partial RISK} = (\beta_1 + \beta_2 \cdot 2 \cdot RISK + \beta_3 AGE + \beta_4 UNI) WAGE \qquad (4)$$

TABLE 5.4: STATISTICS FOR CHOW-TEST

Equation	Independent Variables	Sum of Squared Residuals	Degrees of Freedom
E_1	48	45.092	400
E_2	48	54.536	391
E_R	48	105.544	839

Computed F-statistic: .95

Critical $F_{.01}$: 1.59

Critical $F_{.05}$: 1.39

Equation (4) suggests that market risk premium depends on: (1) the initial levels of risk and wages, (2) age, and (3) union status. Therefore, in order to test the significance of risk in the hedonic wage equation one must look at the combined significance of the variables RISK, RISK**2, RXAGE, and RXUNI. RXAGE and RXUNI are significant at the .99 level of confidence while RISK and RISK**2 are significant at the .98 level of confidence respectively. Therefore, it is concluded that the market does in fact grant a premium based on perceived job-related risk of death. Further, due to the inclusion of occupational dummies in (1) a convincing argument could not be made that RISK is actually a proxy measure for other occupational characteristics - one of which may be risk. OCC accounts for other occupational characteristics not specified in (1). Therefore, it is concluded that the survey instrument did in fact measure individuals' perceptions of job-related risk of death as measured by RISK.

The positive sign on RXUNI suggests that union members get a larger risk premium than do their non-union counter parts. Three explanations for this result are offered. First, Thaler and Rosen suggest that "the lack of free entry into [union] markets renders the typical union member more risk averse than would be true in free markets, forcing firms to pay higher risk premiums in order to entice unwilling union members to work on the riskier jobs." Another explanation is that unions may supply their workers with additional information regarding risk (Olson, 1981). This would affect risk-perceptions. If workers in relatively high risk jobs under perceive job-related risk, due to such psychological factors as risk denial or cognitive dissonance, the added information granted to union workers may adjust their perceptions upwards rendering a larger risk premium demand. Finally, the stronger bargaining power of unions may enable them to receive larger premiums in general - including a premium on risk.

The negative sign on RXAGE may be attributed to the fact that younger workers, although lacking the caution and experience of their older co-workers, have "superior reflexes and recuperative ability" (Thaler and Rosen, p.295). As a result they may be more productive in riskier situations which would render a higher wage rate.

The decision to include variables RISK, RISK**2, RXAGE, and RXUNI in equation (3) was based on economic theory which suggests that the marginal value of safety is dependent on initial levels of risk and wealth, age, and union status. However, it should be pointed out that when RISK**2, RXAGE, and RXUNI were left out of equation (3), the variable RISK faired well by itself. In this situation, the coefficient on RISK was .013 with a t-statistic of 2.5.

The fact that the above cross terms in equation (3) are significant suggests that different risk premiums, according to personal and work environment characteristics, appear in the market. Further, an individual's MVS will also depend on his personal characteristics. In the next section the implied MVS relationship from the above hedonic equation is derived and compared to the MVS measures obtained from the contingent valuation approach used in the survey.

5.3 THE ESTIMATED MVS MEASURES

Equation (4) specifies the slope of the hedonic wage-risk equation. In order to interpret (4) as the marginal value of safety, the following modifications must be made for unit consistency and in order to render an MVS term which is measured in dollars per expected death. First, because R is in terms of deaths per year while W is in terms of dollars per hour, both sides of (4) must be multiplied by total hours per year worked, H. In this fashion, for example, (5) will be transformed in (6)

$$\frac{\partial W \text{ (dollars/hour)}}{\partial R \text{ (deaths/year)}} \tag{5}$$

$$\frac{\partial W \text{ (dollars/hour)}}{\partial R \text{ (deaths/year)}} \cdot \left(\frac{\text{hours}}{\text{year}}\right) = \frac{\partial W \text{ (dollars)}}{\partial R \text{ (deaths)}} \tag{6}$$

Further, since the unit change in deaths is one out of every 4,000 workers employed in the given occupation (6) is actually:

$$\frac{\partial W\text{(dollars)}}{\partial R\text{(death/4,000)}} \tag{7}$$

After being multiplied by 4,000, equation (6) will be in terms of dollars per death; or

$$\frac{\partial W\text{(dollars)}}{\partial R\text{(death/4,000)}} \cdot (4{,}000) = \frac{\partial W\text{(dollars}}{\partial R\text{(death)}}$$

Therefore, in order to interpret (4) as a MVS measure both sides must be multiplied by 4000 l H. In doing this, and utilizing the assumptions made by hedonic studies (specifically that the hedonic wage-risk gradient is formed by a locus of tangencies to the worker-consumer' indifference curves), it can be concluded that:

$$MVS = (\beta_1 + \beta_2 2RISK + \beta_3 AGE \ \beta_4 UNI)WAGE(4000H) \tag{8}$$

Notice that this specification suggests that an individual's MVS depends on initial levels of risk and wealth, age, and union status. This is consistent with the theory in Chapter 2.

Appealing to the estimated coefficients in Table 5.3, equation (8) is estimated to be:

$$MVSH = [.075 - .0066\ (2)RISK - .0015AGE + .027UNI](WAGE)(H)(4000)$$

where MVSH = the implied marginal value of safety from the estimated hedonic equation.

A value for MVSH was then calculated for every individual in the data set. The mean value for MVSH was $2,148,461 and was normally distributed.

In the contingent valuation section of the survey (see question 6 in Appendix A), half of the individuals sampled were asked directly for their willingness to pay for a hypothetical one-unit reduction in job-related risk of death from their initial perceived levels. The other half of the sample was asked there willingness to accept for a hypothetical one-unit increase in job-related risk of death from their initial perceived levels. Since both involve subjective evaluations, it is assumed that the information received in Question 6 reflects individuals' indifference curves. From these WTP and WTA measures two different MVS measures were obtained. Since each step on the ladder in Question 6 is associated with an additional one in 4,000 risk of death from the previous step, multiplying these "bids" by 4,000 yields the marginal value of safety from the CVM. This measure is denoted by MVSS. The results of the contingent valuation are summarized in Table 5.5.

In Table 5.5 $MVSC^+$ denotes the implied marginal value of safety from the contingent valuation for an increase in risk (i.e. willingness to accept-WTA) while $MVSC^-$ denotes the implied willingness to pay (WTP) measure of the marginal value of safety.

TABLE 5.5: CONTINGENT VALUATION ESTIMATES OF MVS

	$MVSC^+$	$MVSC^-$
Mean	5,906,934	2,135,972

Because this approach directly estimates a subjective MVS estimate and since it is assumed that MVS is non-negative,[14] the respondents were constrained to choose from bids ranging from zero to infinity. For $MVSC^-$, the bids in fact ranged from zero to $6,000 (imply_ing MVS estimates ranging from zero to $24 million) with the mean of MVSC equal to $2,135,972. Although the mean values for MVSH and $MVSC^-$ were approximately equal, unlike the distribution of MVSH, $MVSC^-$ was not distributed normally. Specifically, $MVSC^-$ was skewed to the right.

5.4 CONCLUSIONS

The empirical results from the national survey suggest that the distribution of MVS estimates across the sample are quite different depending on the technique employed. Therefore, for a specific individual the implied safety valuation will be different depending on which method policymakers use. However, in order to derive social benefits from some environmental policy, the policymaker is forced to aggregate individual preferences.

In this situation, taking the mean of these individual evaluation is as good a method as any for the purpose of deriving social benefits.[5]

Therefore, the appropriate measure for comparison purposes is the mean of these distributions.

In this study the mean of individual MVS measures from the hedonic technique (MVSH) was found to be approximately the same as the mean of the willingness to pay measure from the contingent valuation ($MVSC^-$). That the mean of $MVSC^+$ (i.e. willingness to accept) is significantly larger, is consistent with the above theory. Further, since most environmental-risk regulation deals with reductions in risk, willingness to pay estimates are the appropriate measures to examine.

By directly comparing the hedonic approach and the contingent valuation method, the results of this study suggest that the two approaches may, in fact, render mean values of the marginal value of safety which are quite similar.[6] Moreover, the $2.1 million MVS figure implied by the hedonic technique in this study is similar to the MVS estimates from other hedonic studies, although slightly higher.[7] Due to the aforementioned error in variables problem found in other hedonic studies, and presuming that this study circumvented such a problem by utilizing a perceived risk measure, one would expect the mean value for MVSH to be different in this study.

To the extent that the results from hedonic studies accurately depict individuals' safety valuations, the results of this study are encouraging for the contingent valuation method because the two methods yielded similar results for this particular risk type (i.e. job-related risk of death.)

If individuals' safety valuations vary across risk types, then the practice of imputing benefits from reductions in environmental risk from job-related risk compensations may be suspect.[8] In this case, one option may be to apply the contingent valuation approach to reductions in specific environmental risk such as exposure to toxic wastes. Valuations in reducing risk types other than job-related risk can be obtained directly from contingent valuation methods due to their flexibility, i.e., they can be applied to a wide spectrum of risk types. The same cannot be said about hedonic techniques.

Although the contingent valuation method appears to fair well when directly compared to the hedonic method, there are some important caveats which should be pointed out with respect to applying this approach to other risk types. As Brookshire et al. (1982) point out:

> [s]ituations where no well-developed hedonic market exists may not be amenable to survey valuation. Biases due to lack of experience must be considered a possibility.

However, they also point out that:

> [e]xisting studies by Randall et al. and Brookshire, Ives, and Schulze, and Rowe et al. of remote recreation areas certainly suggest that survey approaches provide replicable estimates of consumers'

willingness to pay to prevent environmental deterioration, without prior valuation experience.

Therefore, although the hedonic approach cannot be applied to non-job-related risk types while the survey can, much work must be made to ensure that the survey design gives the respondent adequate information regarding the hypothetical market. In Chapter 2 it was noted, however, that the manner in which the survey is designed may affect the survey results. While this dilemma may well be compounded for a risk type where there is no market, it should be pointed out that this is essentially a public good problem, i.e., a reduction in some environmental risk is a public good. The contingent valuation method is one approach towards valuing public goods, including environment risk.

While the criticism aimed at the contingent valuation method are valid, the difficulties involved in evaluating public goods, in general, do not disappear by merely criticizing a particular method aimed at retrieving these valuations. The options are to either improve the existing methods, develop new methods, or simply give up. It is the opinion of this author that an efficient allocation of resources into the production of public goods is crucial as to render the third option a non-option.

Therefore we are left with developing new methods of evaluating public goods in general, and safety in particular, or improving the existing methods. The latter includes a close examination of how the existing approaches compare to each other. This study suggests that, within the realm of safety evaluations, the hedonic approach and the contingent valuation method, when directly compared, yield similar results. While this does not validate the contingent valuation approach as a general method of valuing public goods, it does offer evidence that attempts at improving this method may be a worthy step towards the public goods problem.

REFERENCES

1. If an individual was paid in the form of a salary, WAGE was computed by dividing the individual's yearly salary by his reported total hours work for 1983.

2. The highest education level category, "Advanced College Degree or Profession Degree" has been left out.

3. The highest education level category, "Advanced College Degree or Profession Degree" has been left out.

4. The occupational category "Professional or Technical" has been left out.

5. This amounts to a Benthamite Social Welfare function where each individual is weighted the same. Although the decision to employ any weighting scheme over another involves making normative statements, an equal weighting scheme may be less controversial then, for example, weighting risk-averse preferences more heavily.

6. It should be noted that this result also held for the following subsets of the date file: households with (1) low income levels, (2) middle income levels, (3) high income levels, (4) low π_p levels, (5) middle π_p levels, (6) high π_p levels.

7. These estimates range from $400,000 to $7.5 million, and tend to center around $1.5 million (see Violette and Chestnut, 1983).

8. It has been shown that individuals have different evaluations for different types or risks. See, for example, Starr (1969) and Litai (1980).